Metrology

Laboratory

THEME:

OSCILLOSCOPE

OBJECTIVES:

- to learn how to use a signal generator properly;
- to learn how to use a digital oscilloscope properly;
- to observe various periodic signal shapes;
- to measure signal parameters: period, frequency, magnitude, etc.

EQUIPMENT:

- Dual-trace Oscilloscope
- Signal Generator

BACKGROUND:

Signals

A signal is periodic if its shape repeats consistently over a regular interval of time. Many signals in electronics are periodic, such as the sine wave from the AC mains or clock signals in computers. Other signals are non-periodic (e.g., noise) or transient (a temporary event, like a single pulse). Figure 1 shows a typical sine wave with its key parameters marked.

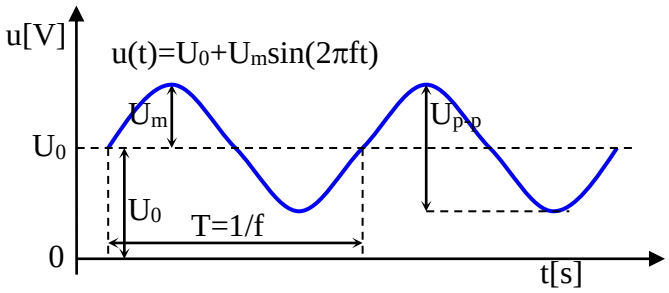

Fig. 1. A generic sine wave: U_m – amplitude, T – period, U_0 – average (DC) value, U_{pp} – peak-to-peak value

- Period (T): The time it takes for one complete cycle of the waveform. It is measured in seconds (s).
- Frequency (f): The number of cycles that occur in one second. It is measured in Hertz (Hz). Frequency and period are complementary: $f = \frac{1}{T}$.
- Amplitude (U_m): The maximum deviation of the signal from its average value. For a voltage signal, it is measured in Volts (V).
- Peak-to-Peak Value (U_{pp}): The total voltage difference between the maximum (peak) and minimum (trough) values of the signal. It is measured in Volts (V).
- Average Value (U_0) / DC Offset: The mean value of the signal over one period. It is measured in Volts (V).

Signal generator

A signal generator (or function generator) is an instrument used to produce known, time-varying voltage signals. Unlike a DC Power Supply, which provides a stable, constant voltage, a generator can produce various waveform shapes (e.g., sine, square, triangle, pulse) over a wide range of frequencies.

Oscilloscope

An oscilloscope is the primary tool used to observe and measure voltage signals over time. A digital storage oscilloscope (DSO) operates by sampling the analog input voltage at a very high speed, converting these samples to digital values (using an Analog-to-Digital Converter, or ADC), storing them in memory, and then drawing them on the display.

This digital approach allows for stable viewing of all signal types (including transients), on-screen measurements, signal storage, and complex analysis (like FFT). The two key limitations are Bandwidth (the maximum signal frequency the scope can accurately measure) and Sampling Rate (how many samples per second it takes).

To display a stable, repeating waveform, the scope must draw it the same way every time. The trigger mechanism tells the scope when to start its sweep, ensuring it always begins at the same point on the waveform (e.g., when the signal crosses 1V while rising).

Manual Measurement

The display of DSO has a grid with visible divisions (div). The scope's current scale settings are always displayed on-screen, typically as Volts/div (vertical axis) and Time/div (horizontal axis). To find a parameter, one must count the divisions and multiply by the scale.

For example, to determine the peak-to-peak value (U_{pp}):

1. Count the number of vertical divisions (Y) from the signal's minimum peak to its maximum peak.
2. Read the Volts/div setting (C_Y) from the screen.
3. Calculate the voltage:

$$\mathbf{Y \bullet C_y = U_{pp} \quad [div \bullet V/div = V]}$$

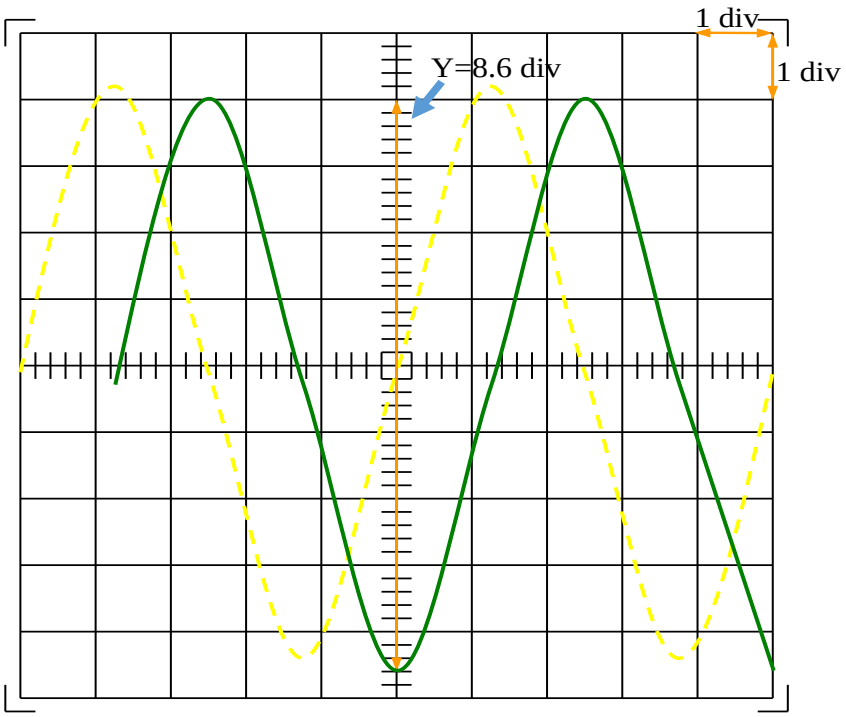

Fig. 2. A picture of the connected signal on the scope's display. Yellow trace is the original view, green trace is the original signal shifted for a better alignment with the grid. Y=8.6 div – is the peak-to-peak value.

The same logic applies to time, using horizontal divisions and the Time/div setting to find the Period (T). Using the vertical and horizontal position knobs to align the signal with the gridlines makes counting divisions much easier. Figure 2 shows signal before (yellow) and after (green) shift leading to set top of the signal aligned perfectly with the main grid, as well as the bottom of the signal placed in the middle of the display for more convenient reading from the subgrid.

Key DSO Functions

AUTOSET: Pressing this button makes the scope analyze the input signal(s) and attempt to find the optimal Vertical, Horizontal, and Trigger settings to display a stable waveform. It is convenient but not always perfect, especially with complex or noisy signals. Caution: this option should be used at the start, as it will overwrite everything set in a mentioned sections.

Vertical & Horizontal Controls: The VOLTS/DIV knob scales the vertical axis (zooms in/out on voltage), and the TIME/DIV knob scales the horizontal axis (zooms in/out on time). The POSITION knobs move the trace up/down and left/right.

Trigger System: This is crucial for a stable display. The TRIGGER LEVEL knob sets the voltage at which the sweep starts. If the trigger level is set above or below the signal, in NORM mode the display will freeze or go blank, as it is waiting for a trigger event that never happens. In AUTO mode, the scope will force a sweep even without a trigger, often resulting in an unstable, rolling display. In the same section it is possible to change the TRIGGER SOURCE.

COUPLING: This setting determines how the signal connects to the scope:

- DC - Shows the complete signal (AC + DC components). This is the default and should be used to measure the total signal, including its DC offset.
- AC - Internally filters out the DC component, showing only the AC part, centered around 0V. This is very useful for viewing a small AC ripple on a large DC voltage.
- GND - Disconnects the input and grounds it. This is used to check where the 0V level is on the screen, allowing for a precise reference.

CURSOR: Provides movable on-screen lines (vertical or horizontal) that allows to measure the exact voltage or time difference between two points.

Modern DSOs have many advanced functions, including Acquire (setting sampling modes), Math (e.g., adding signals or FFT for frequency analysis), displaying multiple channels (CH1, CH2) simultaneously, and XY Mode (plotting one channel against another).

PROCEDURE:

1. **Familiarize with the front panel of the signal generator and oscilloscope and find the following knobs, switches, connectors or options:**

VERTICAL BLOCK

- *INPUTS:* CH1 (X) *and* CH2 (Y)
- *COUPLING:* AC, GND, DC
- Vertical sensitivity *VOLTS/DIV*
- *VERTICAL POSITION*

HORIZONTAL BLOCK

- Horizontal sensitivity *TIME/DIV*
- *HORIZONTAL POSITION*

TRIGGER BLOCK

- *TRIGGER MODE:* AUTO, NORM …
- *TRIGGER SOURCE:* CH1, CH2 …
- *TRIGGER LEVEL*
- *TRIGGER SLOPE*
- *EXT TRIG INPUT*

2. **Single channel measurements**

2.1. Connect the signal generator to the input CH1 of oscilloscope (Fig. 3).

2.2. Generate AC signal according to the requirements.

2.3. Measure V_{pp}, V_m, V_0, T, f using **only** the display (divisions and sensitivities) as it is explained in the “Manual Measurement” section. **Do not** use any additional options or values calculated by the scope itself.

2.4. Measure V_{pp}, V_m, V_0, T, f using CURSOR mode.

2.5. Measure V_{pp}, V_m, V_0, T, f using using MEASURE mode.

2.6 Compare results.

3. **2-channels measurements**.

3.1. Generate two AC signals according to the requirements.

3.2. Connect both signals to the input CH1 and input CH2 (Fig. 4).

3.3. Check how to observe: the first signal; the second signal; both signals.

3.4. Observe both channels changing their frequencies and TRIGGER SOURCE.

3.5. Write down the observations.

4. **Check other options**.

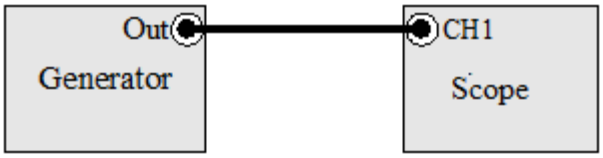

Fig. 3

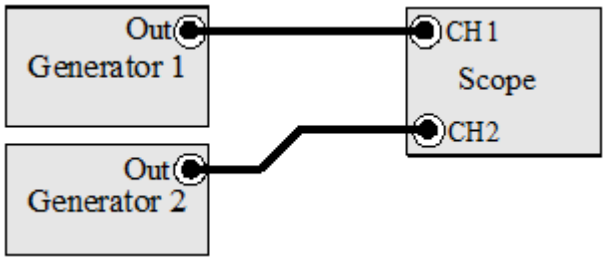

Fig. 4